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Intensity Transformation using Contrast Limited Adaptive Histogram Equalization

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Abstract— ***Histograms are the basis for numerous spatial domain image processing techniques. Histogram manipulation can be used effectively for image enhancement. In addition to providing image statistics, the information inherent in the histogram is also quiet useful in other image processing applications, such as image compression and segmentation. Histograms are simple in manipulation as well as economic for hardware implementations, thus making it a useful tool for image processing. Present study shows - how much it is effective to use Histogram Equalization method for image transformation, its problems and the way-outs in terms of application of Contrast Limited Adaptive Histogram Equalization (CLAHE) technique. The study undertaken is followed by a number of experimental evidences supporting to the empirical findings.***

Keywords—**Histogram Equalization, Contrast Limited Adaptive Histogram Equalization, Intensity Transformation, Colour transformation.**

I. Introduction

Histogram equalization for grey scale image contrast enhancement is a well-known technique in the literature of image processing. Given a grey scale image I with grey levels in the range [0, L-1], its normalized histogram is a discrete function H(l)=nl/n, where the l is the lth grey level, nl is the frequency of occurrence of the corresponding grey level and n is the total pixel population in the image. Histogram equalization can be achieved by using a Cumulative Distribution Function (CDF), and its discrete version is as follows:

$$s_l = T(l) = (L-1)\sum_{j=0}^{l} H(j) = (L-1)\sum_{j=0}^{l}\frac{n_j}{n} \qquad \ldots\ldots\ldots(1)$$

The equation uniformly distributes the pixel population of an image to all the available grey levels of visualization devices, and thus maximizing the contrast. With the rapid development of colour media, the requirement for enhancing colour image has become more and more demanding. Histogram equalization, originally designed for grey scale images has been extended to enhance colour.

Methods in the category of spatial domain are based on direct manipulation of pixels in an image. The spatial domain processing has two distinct categories: Intensity transformation and *spatial filtering*. The Histogram method falls within the category of Intensity transformation. Here it is used for transformation of coloured images.

II. Problems of Intensity Transformation Methods

While considering the intensity transformation by applying Histogram method, we have following difficulties:

i. Less image clarity (i.e., the clarity is not to its fullest intensity)
ii. Unequal contrast projection.

Thus, ordinary histogram equalization uses the same transformation derived from the image histogram to transform all pixels. This works well when the distribution of pixel values is similar throughout the image. However, when the image contains regions that are significantly lighter or darker than most of the image, the contrast in those regions will not be sufficiently enhanced.

Thus, we can think of one step ahead by applying Adaptive Histogram Equalization method to improve the contrast. Here we encounter the following new set of problems:

The adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. It is therefore suitable for improving the local contrast of an image and bringing out more detail. However, AHE has a tendency to over-amplify noise (that is, the random fluctuation of image signals) in relatively homogeneous regions of an image. A variant of adaptive histogram equalization called *contrast limited adaptive histogram equalization* (CLAHE) prevents this problem by limiting the amplification.

Thus, the application of Contrast Limited Adaptive Histogram Equalization (CLAHE) is found to be more suitable alternative as it fulfils all the desired objectives:

i. Image clarity (i.e., the clarity to its fullest intensity),
ii. Equalizing the contrast projection, and
iii. Preventing over-amplification of noise signals by imposing limiting characteristic.

II. Methodology Followed

Application of Contrast Limited AHE

Contrast Limited AHE (CLAHE) differs from ordinary adaptive histogram equalization in its contrast limiting. This feature can also be applied to global histogram equalization, giving rise to Contrast Limited Histogram Equalization (CLHE), which is rarely used in practice. In the case of CLAHE, the contrast limiting procedure has to be applied for each neighbourhood from

which a transformation function is derived. CLAHE was developed to prevent the over amplification of noise that adaptive histogram equalization can give rise to.

This is achieved by limiting the *contrast enhancement* of AHE. The contrast amplification in the vicinity of a given pixel value is given by the slope of the transformation function. This is proportional to the slope of the neighbourhood *cumulative distribution function* (CDF), and therefore to the value of the histogram at that pixel value. CLAHE limits the amplification by clipping the histogram at a predefined value before computing the CDF. This limits the slope of the CDF and therefore of the transformation function. The value at which the histogram is clipped, the so-called *clip limit*, depends on the normalization of the histogram and thereby on the size of the neighbourhood region. Common values limit the resulting amplification between 3 and 4 times the histogram mean value.

It is advantageous not to discard the part of the histogram that exceeds the clip limit but to redistribute it equally among all histogram bins.

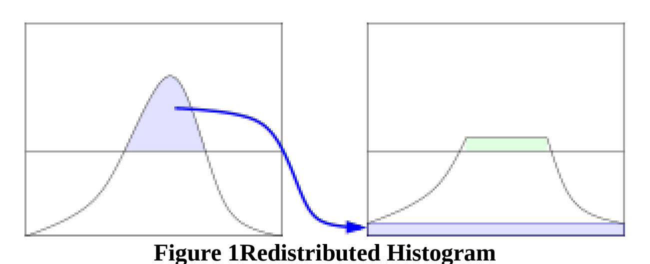


Figure 1Redistributed Histogram

The redistribution will push some bins over the clip limit again (region shaded green in the figure), resulting in an effective clip limit that is larger than the prescribed limit and the exact value of which depends on the image. If this is undesirable, the redistribution procedure can be repeated recursively until the excess is negligible.

To perform the Contrast Limited AHE, Here a balanced algorithm is devised that can be treated as a representative of true picture of the Contrast Limited Adaptive Histogram Equalization (CLAHE).

Algorithm:

1. Obtain all the inputs: Image, Number of regions in row and column directions, Number of bins for the histograms used in building image transform function (dynamic range), Clip limit for contrast limiting (normalized from 0 to 1).
2. Pre-process the inputs: Determine real clip limit from the normalized value if necessary, pad the image before splitting it into regions.
3. Process each contextual region (tile) thus producing gray level mappings: Extract a single image region, make a histogram for this region using the specified number of bins, clip the histogram using clip limit, create a mapping (transformation function) for this region.
4. Interpolate gray level mappings in order to assemble final CLAHE image: Extract cluster of four neighbouring mapping functions, process image region partly overlapping each of the mapping tiles, extract a single pixel, apply four mappings to that pixel, and interpolate between the results to obtain the output pixel; repeat over the entire image.

III. Effect of Histogram Equalization

The image pixels gets evenly distributed over the image space.



Figure 2 (a) An unprocessed image

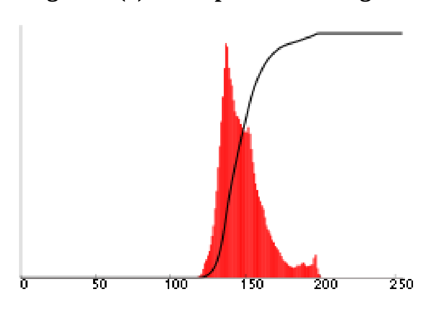


Figure 2 (b) Corresponding histogram (cliffs) and cumulative histogram (black graph-line)



Figure 3 (a) The same image after histogram equalization

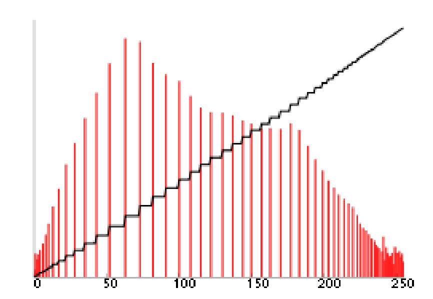


Figure 3 (a) Corresponding histogram (vertical lines) and cumulative histogram (black graph-line)

The results of Contrast Limited Adaptive Histogram Equalization obtained using Matlab R2013a before and after histogram equalization.

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Figure 5(a) Image after applying CLAHE

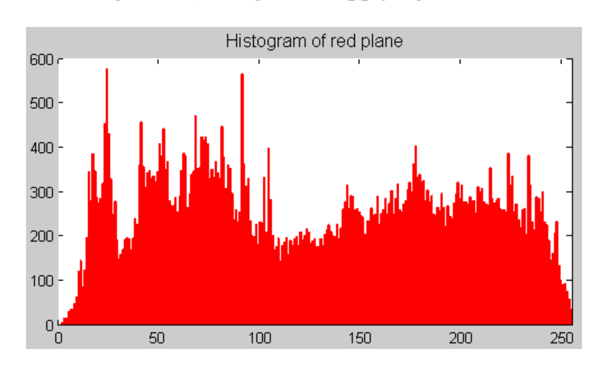


Figure 5(b) R component of image

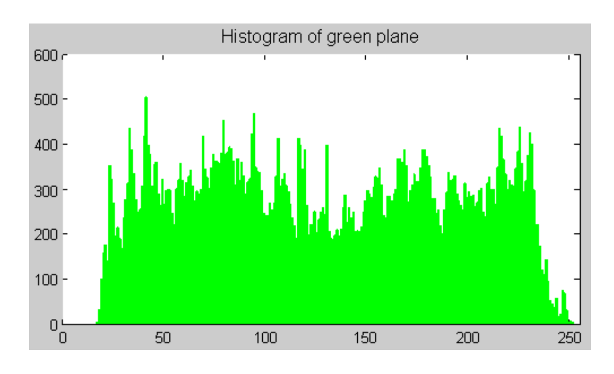


Figure 5(c) G component of image

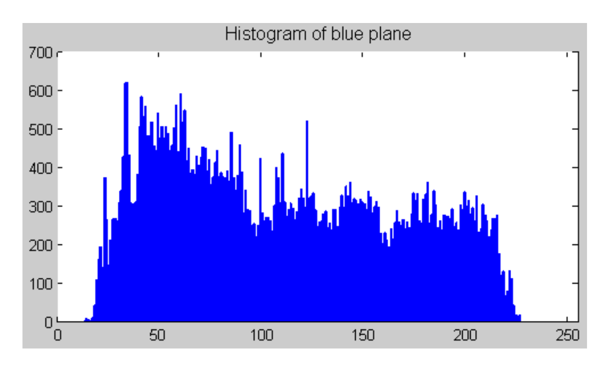


Figure 5(d) B component of image

A distinct comparison can be made between the unequalized histogram and equalized histograms shown in the figure 5 and 6 series. The equalized histogram displays even distribution of gray levels which was missing in case of the unequalized image.



Figure 6(a) Image before applying CLAHE

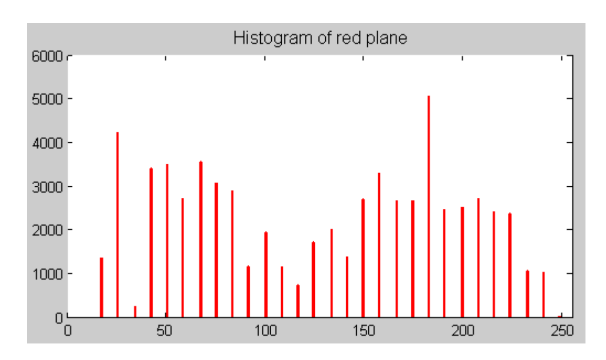


Figure 6b) Equalized R component of image

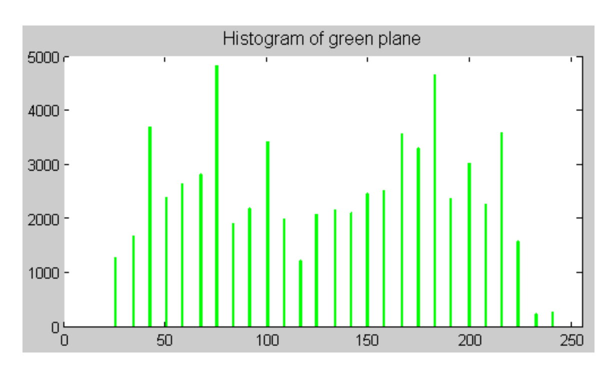


Figure 6(c) Equalized G component of image

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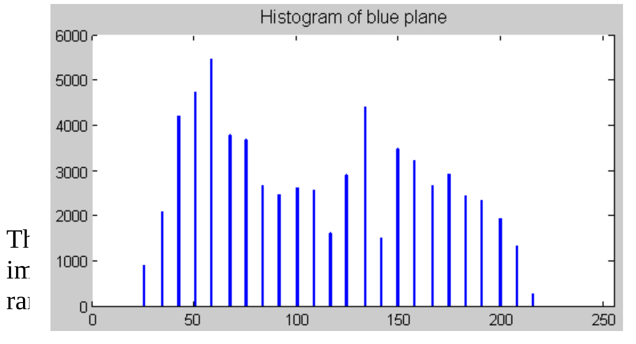


Figure 6(d) Equalized B component of image

Entire experiment suggests that the Contrast Limited Adaptive Histogram Equalization method is far more appropriate in favour of

i. Image clarity (i.e., the clarity is to its maximum intensity),

ii. Equalization of the contrast projection is found to a significant level, and
iii. Over-amplification of noise signals is prevented by limiting the amplification.

It can, therefore, be used for medical imaging and diagnostics with lesser or absolutely no errors getting a better visual quality of images. Though the result of Contrast Limited Adaptive Histogram Equalization (CLAHE) is found to be more better in terms of monochromic images, yet the experiment with colour images also provided quiet a satisfactory empirical result that can readily be used for various practical utilities. It also opens a new avenue for diagnostics and qualitative recovery of images.

IV. Future Scope

The present work can be extended further in the field of medical diagnosis through coloured imaging, which is expected to help in the direction of diagnosis of ailments on the basis of comparative study of relation of colour of affected area under investigation versus lesion. This technique may also be used in the field of qualitative recovery of images through colour reformation.

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